CALIFORNIA AGRICULTURAL EXPERIMENT STATION

REACTION OF CALIFORNIA SOILS

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pH

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Soil reaction, often expressed as pH, affects plant growth, influences soil microörganisms, and serves as an indicator of desirable and undesirable soil conditions. Soil reaction should be considered in the choice of crops and in the selection and use of soil amendments and fertilizers.

While this bulletin discusses these aspects, in a semitechnical manner, its main purpose is to supply long-needed information on the distribution of acid and basic soils in California and the relation to soil series and to soil-forming factors, such as climate, rock material, and drainage.

Since the soil reaction map—to be found in the pocket on the back cover—rests on soil surveys made over a period of decades, its accuracy is not uniform. Later surveys are more precise than former. However, the broad outlines of acid and basic soils are believed to be substantially correct.

Ralph C. Cole, now Chief, Land Classification Section, United States Bureau of Reclamation, Region II, was formerly Assistant Professor of Soils, University of California. When holding this title, he began the study "Reaction of California Soils," which summarizes a large amount of information contained in different soils surveys collected by the author and various members of the Division of Soils. This study was begun at the suggestion of Professor Hans Jenny, to whom the author now wishes to express his indebtedness for the suggestion and continued interest during preparation of the manuscript and the maps.

REACTION OF CALIFORNIA SOILS[1]

Ralph C. Cole

Soil reaction means the degree of acidity or alkalinity of the soil. This degree is indicated by a conventional term—pH—which denotes the concentration of hydrogen ions in the soil—and a number which is known as its value. The pH values of most soils range from about 3.0 to 10.5, with pH 7 designating exact neutrality. Values below 7.0 indicate acidity; those above 7.0, alkalinity or basicity. The pH scale is logarithmic, the concentration of hydrogen ions at pH 6.0 being ten times greater than at pH 7.

The pH scale of soil reaction used in California by the soil survey is as follows:

pH below 5.5	strongly acid soils
pH 5.5–5.9	moderately acid soils
pH 6.0–6.5	slightly acid soils
pH 6.6–7.2	neutral soils
pH 7.3–7.7	slightly basic soils
pH 7.8–8.5	moderately basic soils (this is the range of soils having free lime)
pH above 8.5 (as high as 10)	strongly basic soils (soils usually contain appreciable amounts of exchangeable sodium)

The pH values of the following common substances are listed to make the significance of the soil reaction scale clearer:

increasing acidity ↑	lemon juice	pH 2.2–2.6
	orange juice	pH 3.4–4.0
	sour milk (curdling)	pH 4.6–4.8
	fresh milk	pH 6.6–6.9
	pure water	pH 7.0
increasing alkalinity ↓	human blood	pH 7.35
	sea water	pH 7.5–8.4
	soap solution	pH 8.7–9.9

A thorough study of the natural factors of soil formation primarily responsible for the reaction of California soils indicates three—precipitation; nature of parent material (rock); and drainage. The kind of natural vegetation also influences the pH of the soil. Since natural vegetation itself is correlated with climate, parent material, and drainage conditions, it is more conveniently called a dependent factor. In some instances, the age of the soil must be considered; in areas of high rainfall, for instance, older soils tend to be more acid than recent soils.

PRECIPITATION: low rainfall tends to produce basic soils; high rainfall, acid soils.

During the processes of weathering and soil formation, the minerals of the original rocks (parent material) decompose. Under high rainfall and free drainage, the soluble bases are leached from the soil. Moreover, hydrogen ions from water and carbonic acid will replace adsorbed bases on the colloid particles and produce acid clays. In contrast, in areas of low rainfall the bases set free by weathering will remain in the soil. Since calcium is the most abundant of the bases, and since its carbonates are only slightly soluble, calcium carbonate will tend to form in arid soils.

Accordingly, depending on the degree of leaching, some soils will be high in lime (calcium carbonate), and some will have lime only in the subsoils. Still other soils will be neutral and free of lime, or will possess varying amounts of acidity.

Several good examples of California soils show relationships between amounts of rainfall and soil reaction. Table 1 illustrates the dependency of pH on precipitation for residual soils derived from granitic parent materials. The soils occur on

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hilly relief and have good drainage. Under high rainfall the surface soils are strongly acid.

The soils of the San Joaquin Series are formed on valley-filling materials of mixed composition. They are underlain by hardpan. According to table 2, the types occurring in the Sacramento Valley are more acid than those of the San Joaquin Valley.

The soils of the Yolo sequence (table 3) are formed on recent alluvial materials from sedimentary rock sources. These well-drained soils occur on gently sloping alluvial fans or stream flood plains. They have developed under different conditions of precipitation. The Sorrento soils are slightly basic, with lime in the subsoil; the Yolo soils are neutral to slightly acid; and the Corralitos soils are moderately to strongly acid.

The broader aspects between soil reaction and precipitation in California are depicted in the generalized maps shown in figures 1 and 2. Basic soils are associated with regions of low rainfall, whereas acid soils are restricted to areas of high rainfall. The neutral and the slightly acid or slightly basic soils occur predominantly in the rainfall belt of 10 to 20 inches. The degrees of acidity or alkalinity are influenced also by parent material, topographic features, and age of the soil.

PARENT MATERIAL (ROCK): variation in chemical composition of parent materials causes variation in soil reaction from strongly acid to moderately alkaline.

Parent material—that is, the rock or rock material from which the soil is derived—has a pronounced effect on determining soil reaction. This is especially noticeable in regions of intermediate rainfall, whereas calcareous rocks tend

TABLE 1. Variation of Soil Reaction on Granitic Parent Material under Different Amounts of Rainfall

Soil series	Location	Rainfall	Average reaction	
			Surface soil	Subsoils
		inches	pH	pH
Vista	San Diego County	10–15	6.5	7.1
Holland	San Joaquin County	18–24	5.8	6.8
Holland	Santa Cruz County	40–60	5.3	5.5

TABLE 2. Variation of Soil Reaction in San Joaquin Sandy Loam under Different Amounts of Rainfall

Location	Rainfall	Reaction	
		Surface soil	Subsoils
	inches	pH	pH
Tulare County	5–10	7.1	7.3
Sacramento County	16–20	6.0	7.0

TABLE 3. Variation of Soil Reaction on Recent Alluvium from Sedimentary Rocks under Different Amounts of Rainfall

Soil series	Location	Rainfall	Average reaction	
			Surface soil	Subsoils
		inches	pH	pH
Sorrento	Western San Joaquin County	9–12	7.4	7.7 (calcareous)
Yolo	Colusa County	15–20	6.2	7.0
Corralitos	Santa Cruz County	40–50	5.5	5.6

TABLE 4. Variation in Soil Reaction on Various Kinds of Parent Materials in Eastern Sacramento County

Soil series	Parent material	Reaction	
		Surface soil	Subsoils
		pH	pH
Amador	Light gray rhyolite tuff (Valley Springs formation)	5.0	5.5
Mariposa	Brown slates	5.5	5.5
Auburn	Andesites	6.5	7.0
Pentz	Softly consolidated dull gray sandstone from andesite detritus (Mehrton formation)	7.0	7.0
Ayar	Marly shale	7.6 (calcareous)	7.8 (calcareous)

to produce soils which have alkaline or neutral reaction. Sandstones low in bases give rise to neutral or acid soils. Generally speaking, the richer rock material is in base-forming minerals, the more leaching it will need to produce an acid soil.

A good example of how pH of the soil varies with the type of parent material is found in the foothills of eastern Sacramento County. Five different soil series (table 4) occur adjacent to each other, within a mile or two. All are well drained, occurring on undulating or hilly topography. The rainfall varies from 18 to 24 inches, and the native vegetation consists of grass with scattered oaks. Within this physiographically and climatically uniform region, soil reaction varies from strongly acid to moderately alkaline, in accordance with variations in the chemical composition of the parent materials.

DRAINAGE: a high water table favors accumulation of lime and of white or black alkali, or both; a deep water table has no influence on properties of surface soil.

The extent of drainage conditions in soils constitutes a hydrologic sequence association with the relief of the land. For the purpose of clarification, let us consider specific water table conditions on

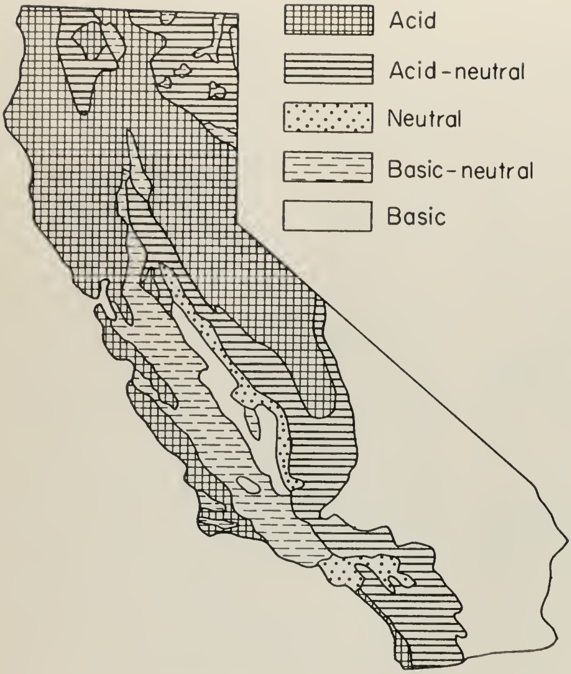
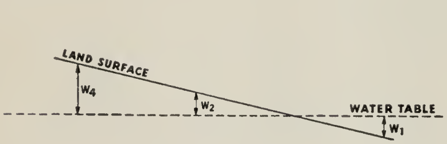


Fig. 1.—Generalized distribution of acid, neutral, and basic soils in California. (From C. B. Hutchison, California Agriculture. University of California Press, 1946.)

gently sloping alluvial lands. Jenny[2] pictures such a condition by the following diagram:



The sloping line represents the soil surface, and the horizontal dashed line the level of the water table. Under these conditions at W_1 the soil is under water; at W_2 the water table is within the zone of capillary rise of water to the surface; whereas at W_4 the water table is so deep that it has no influence on the properties of the surface soil.

In arid climates the presence of a water table within distance of capillary rise of water to the surface enhances the amount of water that evaporates. This is accompanied by a concentration of soluble substances in the soil surface. The upward migration of salts largely, if not wholly, nullifies the effects of leaching by rainfall. Capillary rise favors the accumulation of lime and of white or black alkali, or both.

A good illustration of the reaction changes of height to water table is shown by the coarse-textured alluvial soils of the Dinuba and Fresno series in the vicinity of Modesto in Stanislaus County. This is given in table 5. The Dinuba soils occur on land with variable distances to the water table, whereas the Fresno soils lie just above the overflow land where the water table is practically at the surface during the winter time and within 2 to 5 feet during the summer period.

The presence of black alkali in the Dinuba (b) soils may place the reaction in the subsoil above pH 8.5. In the Fresno soils, the pH is nearly always above 8.5.

It should be pointed out that the Dinuba soils, as defined in the soil survey, consist only of those designated as Dinuba (b). The soils designated as Di-

[2] Jenny, Hans. Arrangements of soil series and types according to functions of soil-forming factors. Soil Science 61:375–91. 1946.

nuba (a), occurring under well-drained conditions with neutral reaction, have not yet been properly named.

Similar drainage sequences but on fine-textured alluvial soils are found in northern Santa Clara County (table 6). In this hydrologic sequence the Dublin soils occur in positions not affected by a water table; the Clear Lake soils have a moderately high water table, and the Sunnyvale soils a very high water table. All of these soils are comparatively free of alkali. Clear Lake has lime in the subsoil; Sunnyvale is calcareous throughout. Intensive pumping in the Santa Clara Valley has placed the water table much lower than when these soils were developed.

COLLOIDAL PARTICLES ADSORB CHEMICAL ELEMENTS

Soils contain clay and humus particles so small they cannot be seen individually, even by microscopic examination. These particles are called colloids. They have the power to adsorb or fix in exchangeable form chemical elements such as calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and hydrogen (H). These adsorbed elements determine a number of very important soil properties, such as structure, availability of plant nutrients, and, to a considerable degree, soil reaction. Sandy soils are low in colloidal particles, whereas clay soils are high.

In soils with neutral reaction, calcium is usually the dominant element on the clay particles. Such clay particles are designated as Ca-clay particles. In other words, Ca-clay particles give a neutral reaction. When lime (calcium carbonate) is present, soil reaction usually varies from pH 7.7 to 8.5, and the colloidal clay particles are virtually saturated with Ca. In arid regions, soluble salts, especially those of sodium, tend to accumulate in the soil. The sodium (Na) ions of the soil solution may displace the calcium ions on the colloidal clay particles. A Na-clay is then formed, usually with an increase in pH.

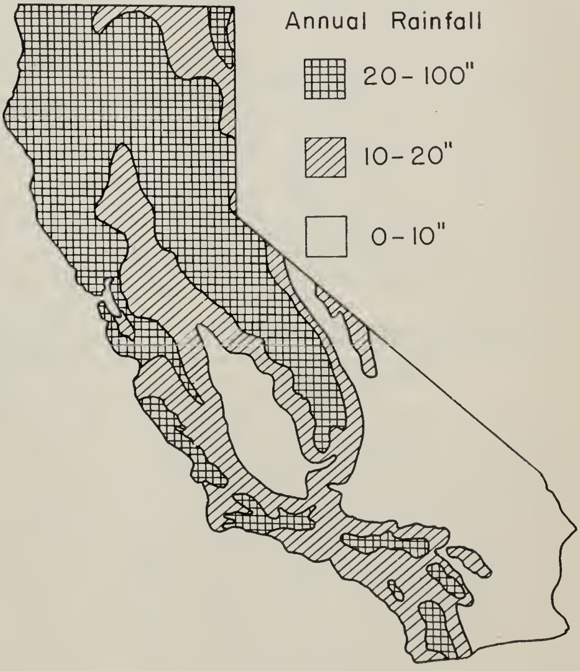


Fig. 2.—Simplified map of annual precipitation in California. (From C. B. Hutchison, California Agriculture. University of California Press, 1946.)

In humid regions, where soils are subject to high rainfall and to leaching, the calcium ions on the soil colloids become displaced by hydrogen ions (H) of water, and the soils assume an acid reaction. Then H-clays are formed. Soil acidity is largely conditioned by H ions adsorbed on colloidal particles.

TWO METHODS DETERMINE SOIL pH

Accurate pH determinations are made most easily with a glass electrode. To 10 grams of dry soil is added 20 cc of distilled water. After a period of several hours, during which the mixture is occasionally shaken or stirred, the glass electrode is inserted into the thick muddy portion of the soil suspension. The pH value, expressed in pH units, is then read off on the instrument dial.

For approximations, colorimetric tests that can be conducted directly in the field are often satisfactory. Colored indicator solutions are added to dry or moist soil, and the resulting color is compared with a color chart indicating pH values or degree of reaction.

The presence of calcium carbonate in the soil may be detected by adding to the sample a few drops of hydrochloric acid (one part concentrated acid to 10 parts water) or some other suitable acid, such as lemon juice, vinegar, or nitric acid. If the soil sample effervesces, the presence of carbonates is indicated.

FERTILIZERS ALTER SOIL REACTION

Pronounced effects on soil reaction result from the use of commercial fertilizers. Different effects are due to differences in the acid-base balance of the fertilizers. Some fertilizers increase the acidity, others reduce it. Ammonium sulfate itself has a slightly acid reaction, and in the soil it tends to augment acidity. This effect may not be marked in one season, but when used continually over a number of years, the changes become pronounced. Sodium nitrate has a tendency to raise the pH. When used over a long period of time the reaction changes may be appreciable. Ammonia (NH_3) is a base, and it may alter the pH of the soil to a marked degree—at least temporarily.

A variety of materials is used deliberately to alter soil reaction. To neutralize soil acidity, some form of lime, such as ground limestone, marl, sugar-beet lime, burned or hydrated lime is used. Calcium of the applied lime displaces the hydrogen ions on the soil colloids and thus reduces acidity. Gypsum, on the other hand, tends to lower the pH of alkaline soils. It also reduces the alkalinity of some alkaline soils. This is brought about by an exchange of the calcium ions for absorbed sodium ions in the soil.

On alkaline soils, sulfur is commonly added to lower the pH toward neutrality. In the soil, sulfur becomes oxidized to sulfuric acid, and this, in turn, neutralizes soil alkalinity.

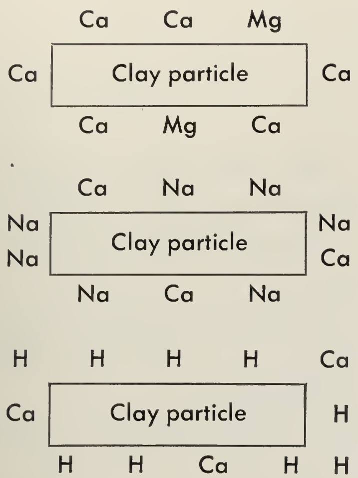
The amount of lime or sulfur to be applied to a soil depends on the degree of acidity or alkalinity on the one hand, and on the kind and amount of soil colloids (clays) on the other. Coarse-textured soils of low clay content need less lime or sulfur to change the reaction by any given amount than fine-textured soils containing great amounts of clay.

The data of Doneen and Lindsay[3] illustrate these conditions by specific examples. Table 7 shows the effect of sulfur in lowering the pH of a light sandy loam soil in Kern County. At a depth of 6 to 12 inches, the acidity is so high (pH 4.4) that it is harmful to plant growth.

Table 8 gives data from Doneen and Lindsay showing the effect of several years' use of ammonium sulfate on the pH of light sandy soils in Kern County. The adjoining untreated soils have pH

[3] Doneen, L. D., and M. A. Lindsay. Effect of sulfur and ammoniacal fertilizers on potato soils in Kern County. February, 1946. (Litho.)

The reaction of clay particles in neutral soils, alkaline soils, and acid soils is shown in the following diagram.



Clay particle with Ca and Mg ions. The reaction is about pH 7.0. **Neutral soils.**

Clay particle containing many Na ions and a few Ca ions. The reaction is basic (pH greater than 7.0). **Alkaline soils,** slick spots.

Clay particle containing many H ions and a few Ca ions. The reaction is below pH 7.0. **Acid soils.**

TABLE 5. Comparison of Soil Reaction as Influenced by Variation in Depth to Water Table (rainfall 10–15 inches; slope 9.5–2 per cent)

Soil series	Depth to highest water table	Reaction	
		Surface soil	Subsoils
	feet	pH	pH
Dinuba (a)	15	6.5	6.9
Dinuba (b)	2–5	7.2	8.3
Fresno	0–1	9.3	9.5

TABLE 6. Comparison of Soil Reaction as Influenced by Variation in Depth to Water Table (sedimentary materials) (rainfall 10–20 inches; slope 0.5–2 per cent)

Soil series	Depth to highest water table	Reaction	
		Surface soil	Subsoils
	feet	pH	pH
Dublin	7–10	6.2	7.1
Clear Lake	2–5	7.1	8.0
Sunnyvale	0–1	7.7	8.2

values ranging from 7.2 to 7.6. The upper portions of the treated soil have become strongly acid.

On the basis of experimental tests with various fertilizer materials, it was surmised long ago that the differences in the effects of fertilizers on soil reaction are due to differences in their acid-base balance. Materials containing an excess of basic elements (potassium, sodium, calcium, or magnesium) over the acid elements (nitrogen, phosphorus, sulfur, and chlorine) tend to reduce soil acidity, whereas materials with an excess of acidic over basic elements tend to increase soil acidity.

Table 9, based on Pierre's work, expresses the relative acidity or basicity in terms of amounts of limestone or sulfur necessary to neutralize the fertilizer effect in soils; table 10 expresses the amounts necessary to neutralize the effect of common soil amendments in soils. Depending on the rate of uptake of acid and basic constituents by plant roots, these relationships may be modified. As indicated above, the physical and chemical makeup of the soil also controls the influence of a given fertilizer on the pH of the soil.

SOIL REACTION AFFECTS PLANT GROWTH AND SOIL MICROÖRGANISMS

Soil reaction affects both plant growth and microörganisms, but the interrelationships are very complex and only partially understood.

Chemical elements like calcium, magnesium, sodium, potassium, and hy-

TABLE 7. pH Values of Untreated and Treated Portions of a Potato Field in Kern County

Depth from top of bed, inches	pH in untreated portion of field	pH in portion of field treated with 1,000 lbs. sulfur per acre
0–6	7.4	6.0
6–12	6.7	4.4
12–18	7.8	5.8

TABLE 8. Effect of Ammonium Sulfate on the pH of Soils on Three Ranches in Kern County

Ranch A		Ranch B		Ranch C	
Depth in inches	pH of soil	Depth in feet	pH of soil	Depth in feet	pH of soil
0–6	5.2	0–1	5.2	0–1	4.7
6–12	4.4	1–2	5.6	1–2	5.0
12–18	6.0	2–3	6.7	2–3	6.8
.....	..	3–4	6.8	3–4	7.5

TABLE 9. Relative Acidity or Basicity of Common Nitrogenous Fertilizers, and Amounts of Lime or Sulfur Required to Neutralize 1 Ton of Each (after Pierre*)

Material	Per cent nitrogen	Relative acidity	Relative basicity	Pounds lime ($CaCO_3$) to neutralize 1 ton	Pounds sulfur to neutralize 1 ton
Nitrogenous fertilizers:					
Ammonium sulfate	21.1	36	...	2,249	...
Ammo-phos	11.0	18	...	1,097	...
Urea	46.6	27	...	1,688	...
Cottonseed meal	6.76	3.6	...	194	...
Sodium nitrate	16.4	..	9.5	....	190
Calcium cyanamide	22.0	..	20.0	....	400

* Pierre, W. H. Industrial and Engineering Chemistry. Analytical Edition 5:220–34. 1933.

drogen, adsorbed on the colloidal particles, have a multiple function. They influence soil reaction, they serve as nutrient elements, and they determine to some degree the physical characteristics of the soil. In addition, colloidal particles containing hydrogen ions (acidity) may exert a harmful effect on plant roots. Moreover, they may affect nutrition by modifying the soil solution and the rate of uptake of ions by plants.

Arnon and Johnson[4] studied the external effect of the hydrogen ion concentration on the growth of plants in water culture solutions where the plants could be well supplied with nutrients. They found that tomato, lettuce, and Bermuda grass plants grew fairly well between pH ranges of 4 and 8. At pH 3 the plants made no growth; at pH 9 the growth was very poor, caused mainly by lack of absorption of phosphorus. Arnon and Johnson found, however, that higher concentrations of calcium were required at pH 4 and 5 than at higher pH values. From this they concluded that at the extremes of the relatively wide physiologically suitable range of external pH between 4 and 8, good growth is possible only if special safeguards assuring a favorable supply of nutrients are observed.

[4] Arnon, D. I., and C. M. Johnson. Influence of hydrogen ion concentrations on the growth of higher plants under controlled conditions. Plant Phys. 17:525–38.

Plants may not be injured directly by moderate degrees of soil acidity or alkalinity. However, there are many indirect effects in soils that may be unfavorable to plant growth.

In soils, under increasingly acid conditions, iron, aluminum, and manganese become more and more soluble. Iron and aluminum combine with soluble phosphates to form very insoluble iron and aluminum phosphate compounds, and thus decrease the availability of phosphorus to the plants. Furthermore, soluble aluminum even in very small amounts is toxic to plants. Manganese, although essential to plants in minute concentrations, becomes toxic if present in appreciable amounts. As the adsorbed H ions (soil acidity) increase, the amount of calcium, and, to some extent, magnesium becomes less. The plant thus suffers a double disadvantage. Its increased physiological demand for calcium is met by a lowered supply.

On the alkaline end of the reaction scale at high pH values, the phosphorus compounds are less soluble than at neutral reaction. The compounds of iron and manganese and some of the microelements precipitate and become unavail-

able. At pH values above 8.5 appreciable amounts of sodium ions are replacing calcium on the colloidal particles, bringing about a very unfavorable physical condition of the soil.

Reactions in California soils range from pH values of 4 (podzol-like soils near the Mendocino Coast) to pH values above 10 (alkali soils), the predominant range being from 5.0 to 8.5. Many crops grown in the state are capable of satisfactory growth over much of this range of soil reaction. However, there are some very important crops which have difficulty in making good growth in acid or alkaline soils. Alfalfa, sugar beets, sweet clover and some of the other clovers seem to prefer soils which are near neutral or slightly alkaline in reaction. They also do well in calcareous soils; but they are sensitive to strongly acid soil conditions. Yields of these crops tend to drop off when soil reactions fall below pH 6.0, except in the presence of high amounts of exchangeable calcium.

On the other hand, most tree fruits are able to grow well in soils with pH values as low as 5.0, but many suffer from iron deficiency (chlorosis) when the lime content is high.

It should be emphasized that crops can withstand greater extremes of unfavorable soil reaction when the supply of available nutrients, especially calcium, is high. On most mineral soils having pH values below 6.0, alfalfa and sugar beets grow poorly, yet in the Sacramento-San Joaquin River Delta region there are areas of acid organic soils where very excellent yields of these crops are found. The organic soils are capable of supplying high amounts of calcium even at moderately low pH values. There are, however, fields in this area where soil acidity is so high that poor yields and even failures of sugar beets and alfalfa have been observed.

Soil reaction affects not only crops but also microörganisms living in the soil. They, in turn, also influence crop growth. Usually the more beneficial microörganisms prefer soil reactions between pH 6.0 and 8.0. In strongly acid soils, legume bacteria fail to develop and function normally. Nitrifying organisms also are sensitive to strongly acid conditions. On the other hand, certain fungi flourish in moderately to strongly acid soils. They do less well in soils which are neutral or basic.

TABLE 10. Relative Acidity or Basicity of Common Soil Amendments Used in California and the Amount of Lime or Sulfur Required to Neutralize 1 Ton of Each (after Pierre*)

Material	Per cent sulfur	Relative acidity	Relative basicity	Pounds lime ($CaCO_3$) to neutralize 1 ton	Pounds sulfur to neutralize 1 ton
Sulfur	100.0	100	...	6,250	...
Sulfur dioxide	50.0	50	...	3,125	...
Sulfuric acid	33.0	33	...	2,041	...
Ferrous sulfate	11.0	11	...	687	...
Gypsum	18.5	0	...	0	...
Limestone	...	...	100	...	640
Sugar-beet lime	...	...	40–60	...	256–384

* Pierre, W. H. Industrial and Engineering Chemistry. Analytical Edition 5:220–34. 1933.

Certain plant diseases are caused by soil organisms. A change in the soil reaction often is an effective control for such diseases. For instance, potato scab is caused by actinomyces organisms, and may be controlled by maintaining the pH of the soil at 5.5 or less. At this reaction the disease-producing organism becomes inactive, while the potato plant still maintains growth. The disease which causes club root in cabbages and other crucifers is produced by a fungus that is inactive in neutral or alkaline soils, but flourishes in acid soils. Fortunately, most crucifers grow well in neutral soils and satisfactorily in calcareous soils.

SOIL REACTION MAP OF CALIFORNIA

In preparing a soil reaction map of California, soils were arranged in five groups.

Moderately to strongly acid soils (Symbol A). These soils are acid throughout the profile, with the surface soil often more acid than the subsoil. The pH values are usually between 5.5 and 6.0.

Slightly acid soils (Symbol S). The surface soil varies in pH from about 6.0 to 6.5. The subsoil may also be slightly acid, or it may be neutral.

Neutral soils (Symbol N). The reaction of these soils is in the vicinity of neutrality (pH 6.6 to 7.2).

Soils having calcareous subsoils (Symbol +). These soils contain free lime (calcium carbonate) in their subsoils. Strictly speaking, the pH of a calcareous soil depends on the carbon dioxide content of the soil solution, but for most soils containing lime it varies between 7.7 and 8.5. In other words, the soils of this group have moderately alkaline subsoils, whereas the surface soils are usually neutral in reaction.

Soils having calcareous surface and subsoils (Symbol ++). These soils are calcareous and therefore moderately basic throughout their profile.

Many California soils are classified as alkali soils. Their reactions may be considerably higher than pH 8.5; in fact, some reach values of pH = 10 (sodium carbonate soils). It is impossible to delineate these areas on the soil reaction map. A very generalized soil alkali map appears on page 348 of "California Agriculture," by C. B. Hutchison, and printed by the University of California Press, 1946.

The data for the compilation of the soil reaction map found in the pocket at the back of this publication were taken from soil surveys made by the University of California and agencies of the United States Department of Agriculture. On the map of figure 3A each area is marked by a number which permits identification of the area with the aid of the soil survey key in figure 3B.

In California approximately 380 different soil series and over 1,100 types have been mapped. These have been established on the basis of soil properties, one of which is soil reaction. In general, the reaction of each soil series is confined to fairly narrow limits. There are, however, some soil series, especially older ones, which show considerable variation in pH. In recent soil surveys, more attention is being given to soil reaction than in earlier surveys. There are now a number of older soil series which have been separated into two or more series in accordance with differences in reaction. For example, the Yolo Series, as mapped in a number of older soil surveys, includes the following:

Mocho—calcareous throughout
Sorrento—calcareous subsoils
Yolo—neutral
Corralitos—moderately to strongly acid

The original Hanford Series, mapped extensively in the San Joaquin Valley, now includes the following:

Grangeville—calcareous throughout
Hesperia—calcareous subsoils
Hanford—neutral

The characteristic reactions of all the soil series mapped in California are given in table 11. These reactions will, in general, correspond to those listed in the various soil survey reports. Where there are discrepancies, the reactions listed in table 11 supersede those appearing in earlier publications.

INTERPRETATION OF SOIL REACTION MAP

In order to bring out more clearly some of the relationships between rainfall, parent material, and drainage conditions on the one hand, and soil reaction on the other, schematic transect graphs have

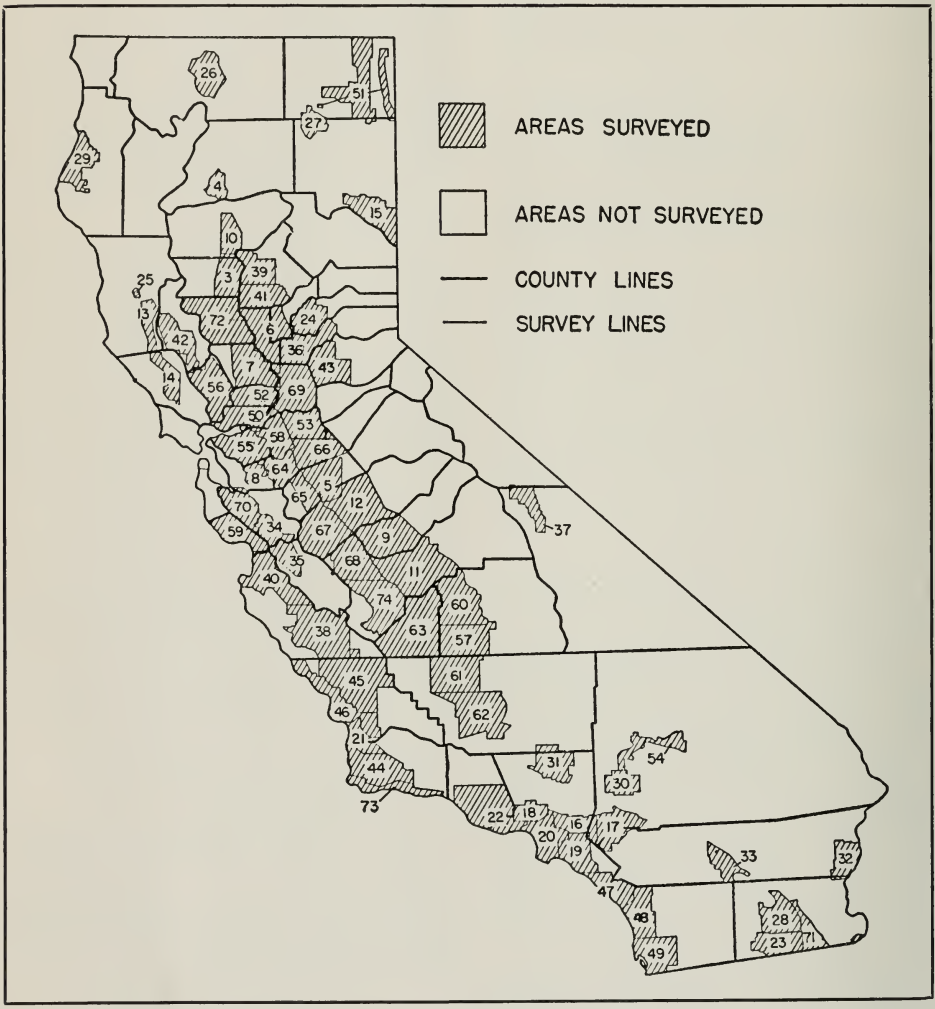


Fig. 3A.—Soil survey areas in California. The numbers refer to the key on the facing page. (From C. B. Hutchison, California Agriculture. University of California Press, 1946.)

been constructed. Four of them extend across the Central Valley and three across the coastal regions. Elevations and widths of bands do not represent specific magnitudes. They are intended to show the relative physiographic positions and the sequences of the various series.

The transects demonstrate that, in general, soil reaction correlates with rainfall, but it is materially modified and in places definitely dominated by the nature of the parent materials or the drainage conditions. The soils on the west side of the San Joaquin Valley are derived

No.	Area	Date of survey	No.	Area	Date of survey
	Around Fresno*	1900	29	Eureka	1921
	Around Santa Ana*	1900	30	Victorville	1921
	Hanford*	1901	31	Lancaster	1922
	Soledad Sheet*	1901	32	Palo Verde	1922
	Lower Salinas Valley*	1901	33	Coachella Valley	1923
	Ventura*	1901	34	Gilroy	1923
	San Gabriel*	1901	35	Hollister	1923
	Imperial Valley*	1901	36	Auburn	1923
	San Jose*	1903	37	Bishop	1924
	Imperial*	1903	38	King City	1924
	Indio*	1903	39	Chico	1925
	Los Angeles*	1903	40	Salinas	1925
	Bakersfield*	1904	41	Oroville	1926
	Sacramento*	1904	42	Clear Lake	1927
	YumaArea,Arizona-California*	1904	43	Placerville	1926
	San Bernardino Valley*	1904	44	Santa Ynez	1927
	Stockton*	1905	45	Paso Robles*	1928
3	Colusa*	1907	46	San Luis Obispo	1928
4	Redding*	1907	47	Capistrano*	1929
	Klamath Reclamation Project*	1908	48	Oceanside*	1929
5	Modesto-Turlock*	1908	49	El Cajon*	1929
	Pajaro Valley*	1908	50	Suisun	1930
	Porterville*	1908	51	Alturas*	1932
6	Marysville*	1909	52	Dixon	1931
7	Woodland*	1909	53	Lodi	1932
8	Livermore Valley*	1910	54	Barstow	1932
9	Madera*	1910	55	Contra Costa*	1933
10	Red Bluff*	1910	56	Napa	1933
11	Fresno*	1912	57	Pixley	1935
12	Merced*	1914	58	Delta	1934
13	Ukiah*	1914	59	Santa Cruz	1935
14	Healdsburg*	1915	60	Visalia	1934
15	Honey Lake	1915	61	Wasco	1935
16	Pasadena	1915	62	Bakersfield	1936
17	Riverside	1915	63	Kings County†	1937
18	San Fernando*	1915	64	Tracy	1938
19	Anaheim	1916	65	Newman†	1938
20	Los Angeles	1916	66	Stockton†	1939
21	Santa Maria	1916	67	Los Banos†	1939
22	Ventura	1917	68	Mendota†	1940
23	El Centro	1918	69	Sacramento†	1941
24	Grass Valley	1918	70	Santa Clara†	1941
25	Willits	1918	71	East Side Mesa	1942
26	Shasta Valley	1919	72	Colusa County†	1942
27	Big Valley	1920	73	Santa Barbara†	1943
28	Brawley	1920	74	Coalinga†	1943

* Out of print; may be consulted in the principal public libraries.
† Not yet published.

Fig. 3B.—Areas in California covered by detailed soil surveys.

TABLE 11. Soil Series of California Classified by Symbol According to Their Reaction

Acolita	+ +	Cachuma	N	Docas	+ +	Hartley	S
Adelanto	+	Cajon	+ +	Domino	+ +	Henneke	N
Agate	N	Calera	+ +	Dorado	S	Herdlyn	+
Ager	+	Caliente	+ +	Drylyn	+ +	Hesperia	+
Agueda	+ +	Campbell	+	Dublin	N	Hillgate	S
Aiken	S	Camphora	N	Ducor	+	Hilmar	S
Alamitos	N	Canby	+	Dunnigan	+	Holcomb	A
Alamo	+	Capay	+			Holland	S
Aliso	+	Carlsbad	S	East Park	N	Holtville	+ +
Altamont	+	Carpinteria	N	Edenvale	+	Honcut	N
Alviso	+ +	Carrisalitos	N	Edison	+	Hopeton	+
Amador	A	Carrizo	+ +	Egbert	S	Hornitos	S
Ambrose	+	Carson	+	Elder	N	Hovey	+ +
Anderson	N	Castro	+ +	Elkhorn	S	Huerhuero	+
Anita	N	Cayucos	S	Elna	+ +	Hugo	A
Antelope	N	Chamisal	S	Empire	A		
Antioch	+	Chamise	A	Escondido	N	Imperial	+ +
Antone	+	Chino	+	Esparto	S	Indio	+ +
Arbuckle	N	Chualar	N	Exeter	N		
Arguello	S	Churchill	+ +			Jalama	S
Arnold	A	Clear Lake	+	Fallbrook	N	Johnstonville	+
Atascadero	S	Climax	+	Farallone	S	Julian	S
Athlone	N	Coachella	+ +	Farwell	+		
Atwater	N	Cole	S	Feather	S	Keefers	S
Auburn	S	Colma	S	Felton	A	Kern	+ +
Ayar	+ +	Columbia	N	Ferndale	A	Kettleman	+ +
Azule	S	Colusa	+ +	Flournoy	S	Keyes	A
		Cometa	N	Forgeus	N	Kimball	S
Bale	S	Commatti	+	Fort Bragg	A	Kirkwood	N
Ballard	S	Conejo	N	Foster	+ +	Klamath	A
Ballico	A	Contra Costa	N	Freeport	+	Kneeland	A
Barron	S	Coombs	S	Fresno	+ +	Konokti	S
Bayshore	+ +	Coquille	A				
Bayside	A	Corning	S	Garey	S	La Branza	+
Baywood	A	Corralitos	S	Gaviota	N	Laguna	S
Bear	N	Correra Peat	A	Gazelle	+ +	Lahonton	+ +
Bear Creek	S	Cortina	N	Genevra	+	Landlow	+
Bellavista	+ +	Cotati	A	Gila	+ +	La Paloma	A
Bellegrave	+ +	Cowell	S	Glamis	+ +	Las Flores	S
Ben Lomond	A	Cropley	+	Glann	S	Las Posas	N
Berenda	+	Crow Hill	S	Gleason	N	Lassen	+
Berryessa	+	Cuyama	+ +	Gloria	N	Laughlin	S
Bieber	N	Cuyamaca	S	Goldridge	A	Laveen	+ +
Bishop	+ +			Gorman	S	Leesville	N
Blucher	S	Daggett	+ +	Gould	N	Lethent	+ +
Bonsall	N	Danville	N	Grangeville	+ +	Levis	+ +
Borden	+	Delaney	S	Graton	S	Lewis	+ +
Botella	N	Delano	+	Greenfield	N	Lindo	+
Bowers	+ +	Delhi	N	Gridley	N	Lindsey	+
Brentwood	+	Dello	+	Grimes	+	Lingard	+
Bryant	+	Denison	S			Linne	+ +
Buntingville	+	Denverton	+	Hacienda	+ +	Llano	S
Burns	A	Diablo	+	Hames	S	Lockwood	S
Butte	S	Diamond Spring	S	Hanford	N	Lodo	S
		Dinuba	+	Harrington	N	Los Banos	+

TABLE 11—Continued

Los Gatos	S	Oakley	S	Russell	+ +	Tahoe	S
Los Osos	A	Occidental	A	Rydberg	A	Talmage	S
Los Trancos	N	Oceanview	A	Ryde	S	Tangair	A
Lost Hills	+ +	Ohmer	S	Ryer	+	Tehama	N
Lyndyl	+ +	Ojai	N			Tejon	+
		Olcott	N	Sacramento	+	Temple	+
Madera	+	Olivenhain	S	Salinas	+	Tierra	S
Manzanita	A	Olympic	A	San Andreas	S	Tijeras	+ +
Marcuse	+	Orestimba	+	San Emigdio	+ +	Topo	+ +
Marguerite	N	Orita	+ +	San Joaquin	S	Traver	+ +
Marina	A	Ortigalita	+	San Marcos	+	Tubac	+
Mariposa	A	Oxalis	+ +	San Timoteo	+ +	Tujunga	N
Marvin	+			San Ysidro	S	Tulare	+ +
Maxwell	+	Pacheco	+	Santa Lucia	S	Tuscan	N
Maymen	S	Pachappa	+	Santa Rita	+ +	Twin Oaks	+
Maywood	S	Pajaro	A	Santa Ynez	N		
McClusky	A	Panhill	+	Saratoga	S	Ulmar	+
McCoy	N	Panoche	+ +	Sebastopol	A	Underwood	+
McNabb	N	Pentz	N	Sespe	+		
Melbourne	A	Perkins	S	Seville	+	Vallecitos	N
Meloland	+ +	Permanente	+ +	Shasta	N	Venado	+ +
Mendocino	A	Pescadero	+	Shedd	+ +	Venice	A
Merced	+	Peters	N	Sheridan	S	Vina	N
Merriam	+	Pinole	S	Sierra	A	Visalia	N
Merrill	+ +	Pinto	A	Siskiyou	S	Vista	N
Metz	+ +	Piper	+ +	Sites	A	Volta	+ +
Milagra	N	Pit	N	Sobrante	S		
Milham	+ +	Placentia	N	Solano	+	Wapato	A
Milpitas	S	Plainsburg	+	Soper	N	Wasioja	+
Mocho	+ +	Planada	+	Soquel	S	Watsonville	A
Modoc	N	Pleasanton	N	Sorrento	+	Waukena	+ +
Mohave	+	Pond	+ +	Snelling	S	Westport	A
Mono	+ +	Porterville	+	Spore	N	Whiterock	A
Monserate	+	Positas	N	Stacy	+ +	Whitlock	+ +
Montague	+	Prado	+	Standish	+ +	Whitney	N
Montara	N	Preston	+ +	Staten Peaty		Willits	A
Montezuma	+	Purisima	S	Muck	A	Willows	+
Moreno	+ +			Steinbeck	A	Woodrow	+ +
Mormon	+	Ramada	N	Stockpen	+	Wright	A
Moro Cojo	A	Ramona	N	Stockton	+	Wyman	N
Mottsville	A	Raynor	+	Stonyford	S		
Myers	N	Redding	A	Sunnyvale	+ +	Yokohl	N
		Rincon	+	Sunol	N	Yolo	N
Nacimiento	+ +	Ripperdan	N	Sunrise	+ +	Ysidora	N
Narlon	S	Roberts Muck	A	Superstition	+ +	Ytias	+ +
Niland	+ +	Rocklin	S	Surprise	N	Yucaipa	N
Nord	+ +	Rohnerville	A	Sutter	N		
Norman	+	Rosamond	+ +	Sweeney	S	Zaca	+ +
		Rositas	+ +	Sycamore	+	Zamora	N
Oakdale	N	Rossi	+ +			Zanja	S
Oak Glen	N	Rumsey	+				

Symbol: A = Moderately to strongly acid soils.
S = Slightly acid soils.
N = Neutral soils.
+ = Soils having calcareous subsoils.
+ + = Soils having calcareous surface and subsoils.

mainly from marine sedimentary rocks, whereas those on the east side are formed mainly on granitic rocks. Under comparable rainfall and under good drainage conditions, the pH values of the soils from sedimentary rocks are usually higher than those from granitic rocks. In the valley trough, where drainage is sluggish and where the water table is high during a considerable portion of the year, the soils have higher pH values than do the soils on either side of the valley trough.

Along the areas adjacent to the coast the rainfall is usually lower than at higher elevations on the slopes of the Coast Range Mountains. In a number of instances, however, the soils along the coast may be more acid than some of the soils occurring at higher elevations farther inland. The coastal soils are often sand and contain relatively few bases. Consequently, they are readily leached and easily become acid. Some of the soils in the upland areas are derived from calcareous shales. Water percolation is slow; hence, these soils may have higher pH values. The transect maps will be found in the pocket on the back cover.

SUMMARY

Soil reaction is the degree of acidity or alkalinity of the soil. It is usually expressed quantitatively in pH units. The degree of soil reaction is dependent mainly upon three important soil-forming factors: climate, parent material, and drainage. In general, soils in areas of high rainfall are acid and those in areas of low rainfall are basic. Soils formed from parent materials high in calcium, magnesium, potassium, and sodium are less likely to be acid than those formed from parent materials low in these elements. Soils in arid areas formed under conditions of high water table are more basic than those formed where drainage is adequate.

The nature of the soil reaction often affects the type of plants that can be grown. There are certain very important crops, such as alfalfa, sugar beets, and some of the clovers, which do not grow well in moderately acid or strongly acid soils, but produce very well in soils which are highly calcareous. On the other hand, lemons and a number of other tree fruits are sensitive to soils high in lime, but do well in moderately acid soils.

Soil reaction also affects the nature of the microörganisms within the soil. In general, bacteria and actinomyces grow well in soils with reactions near neutral to basic, whereas fungi prefer soils which are acid in reaction. Some of these microorganisms, such as nitrifying bacteria, do valuable service to plants, whereas a number of plant diseases are caused by soil microörganisms. In some cases the control of the disease can be effected by control of the soil reaction.

The reaction of the soil can be altered by the use of amendments. The principal amendments are lime to reduce acidity and sulfur to increase it. The soil reaction of some soils is materially altered by the application of certain fertilizers. For instance, ammonium sulfate increases the acidity of sandy soils.

The distribution of the soils in California, according to their reaction, is shown on a series of maps in the pocket on the facing cover. This distribution is mainly correlated with the amount of rainfall, but there are local variations dependent on other factors, such as parent material and drainage conditions.

8*m*-4,'49 (B1689)

MODERATELY TO STRONGLY ACID

SLIGHTLY ACID

NEUTRAL

CALCAREOUS SUBSOIL

CALCAREOUS SURFACE AND SUBSOIL

MISCELLANEOUS SOIL MATERIAL, INADEQUATE DATA OR UNSURVEYED

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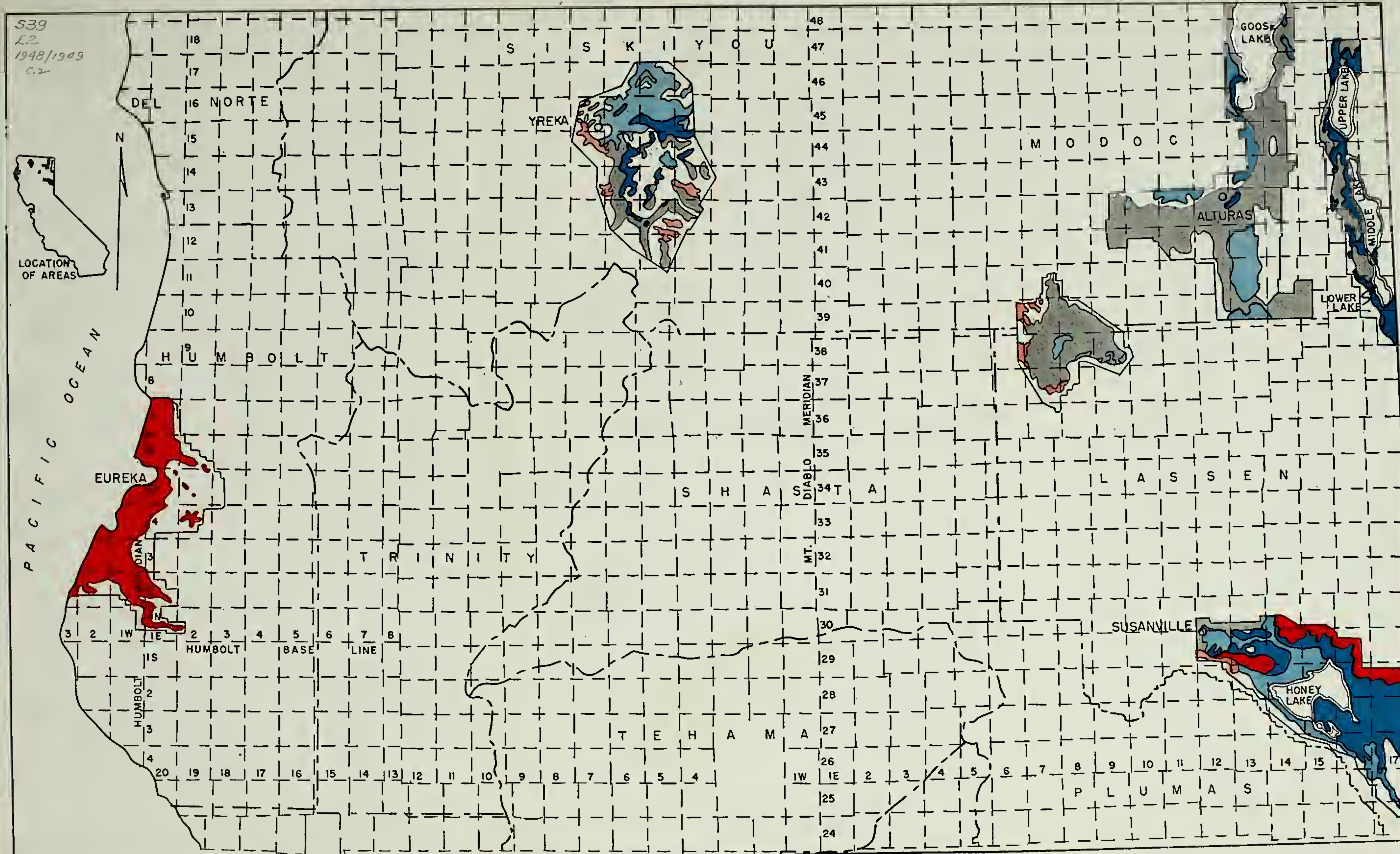
SISKIYOU
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YREKA
MODOC
GOOSE LAKE
UPPER LAKE
MIDDLE LAKE
LOWER LAKE
ALTURAS
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LOCATION OF AREAS
HUMBOLT
PACIFIC OCEAN
EUREKA
TRINITY
SHASTA
MT. DIABLO MERIDIAN
LASSEN
SUSANVILLE
HONEY LAKE
TEHAMA
PLUMAS
HUMBOLT BASE LINE
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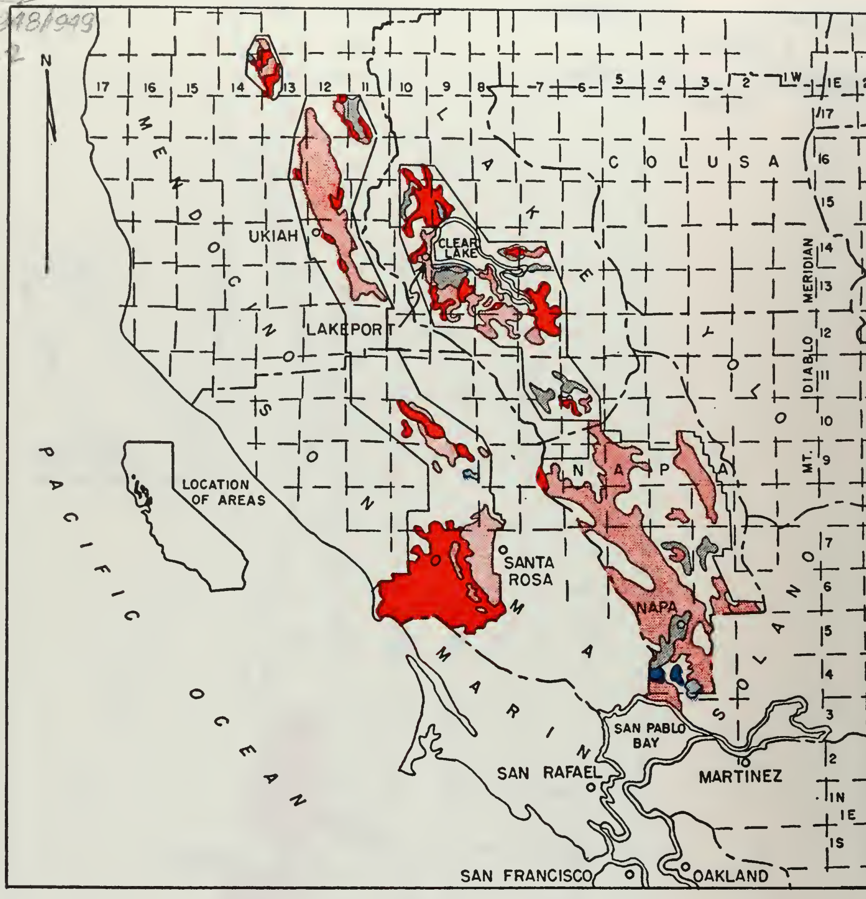
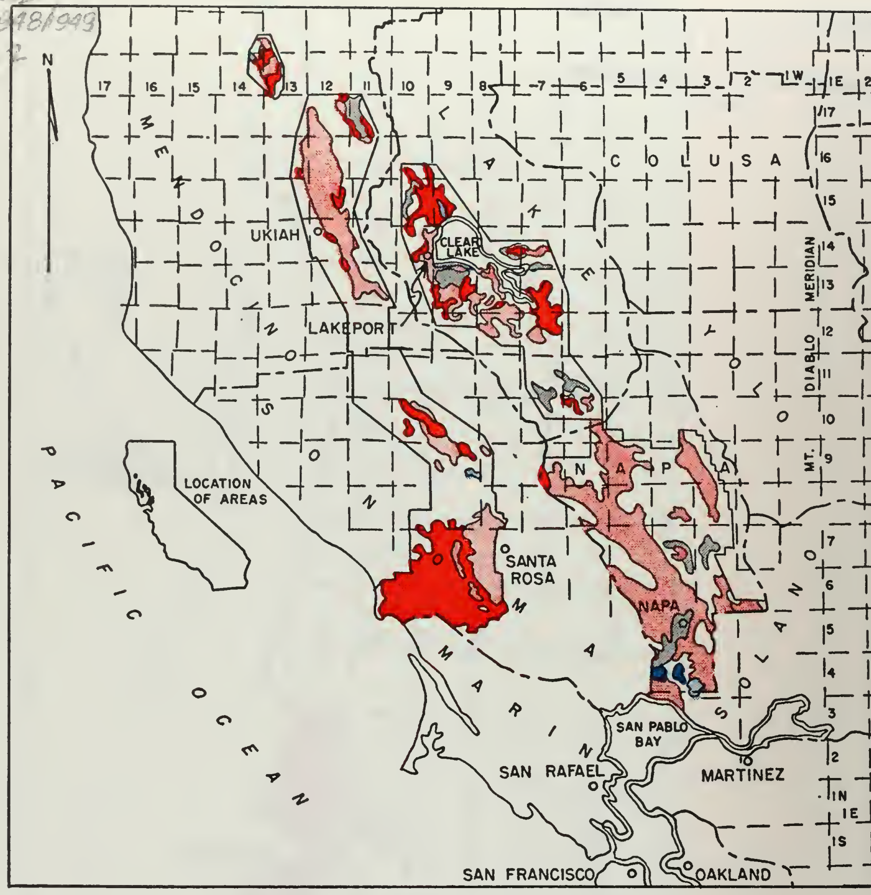
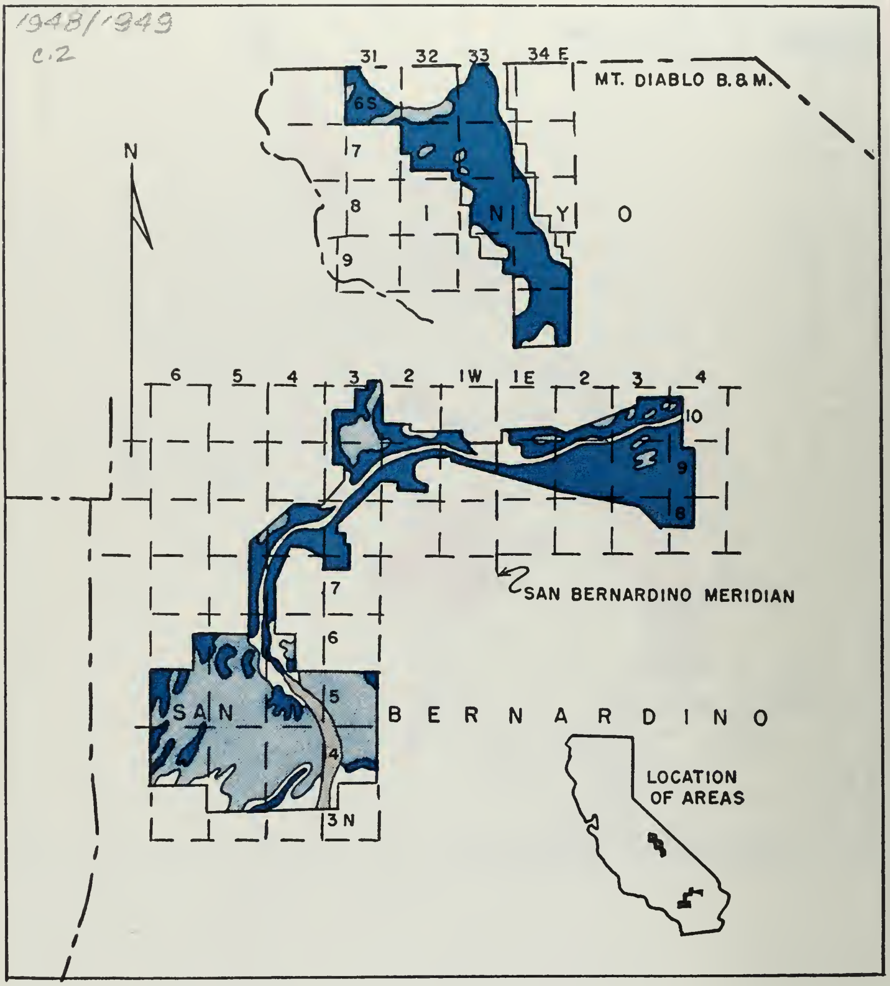



N
MENDOCINO
LAKE
COLUSA
UKIAH
CLEAR LAKE
LAKEPORT
YOLO
SONOMA
NAPA
SOLANO
LOCATION OF AREAS
PACIFIC OCEAN
SANTA ROSA
NAPA
MARIN
SAN PABLO BAY
SAN RAFAEL
MARTINEZ
SAN FRANCISCO
OAKLAND
MT. DIABLO MERIDIAN


MT. DIABLO B.& M.
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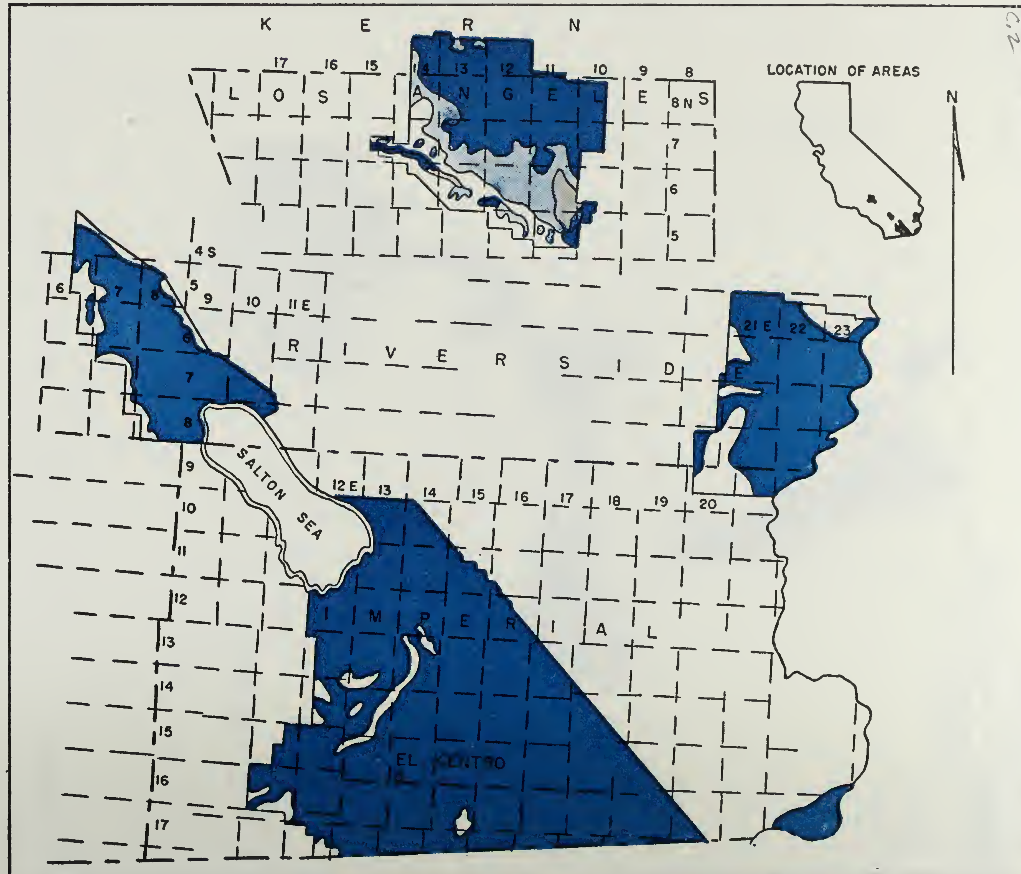
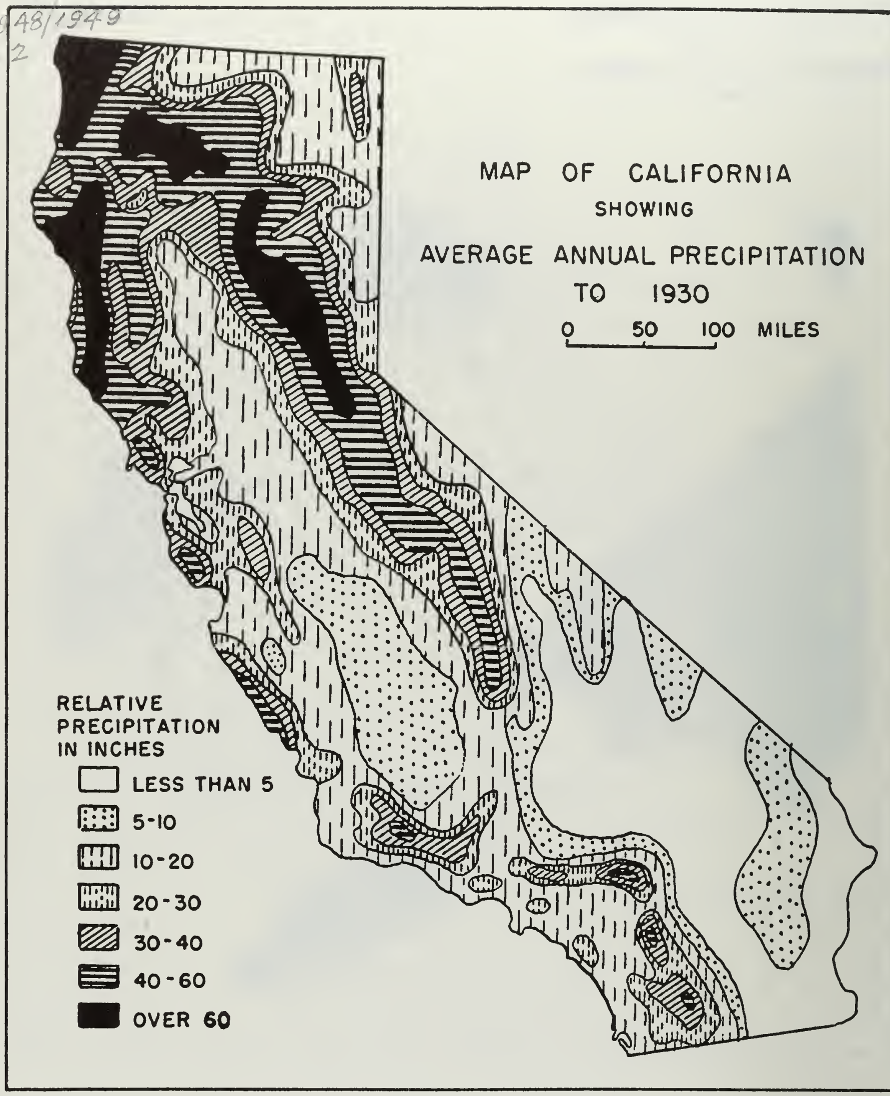
SAN BERNARDINO MERIDIAN
SAN BERNARDINO
LOCATION OF AREAS


K E R N
L O S A N G E L E S
R I V E R S I D E
I M P E R I A L
SALTON SEA
EL CENTRO
LOCATION OF AREAS
N

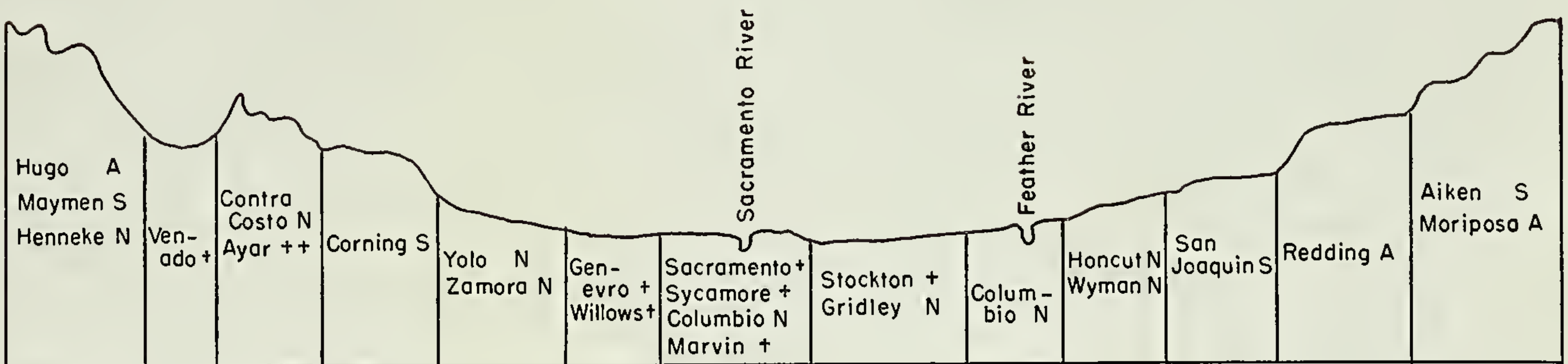

MAP OF CALIFORNIA
SHOWING
AVERAGE ANNUAL PRECIPITATION
TO 1930
0 50 100 MILES
RELATIVE
PRECIPITATION
IN INCHES
LESS THAN 5
5-10
10-20
20-30
30-40
40-60
OVER 60

LOCATION OF AREAS
RED BLUFF
OROVILLE
WILLOW
COLUSA
YUBA CITY
MARYSVILLE
AUBURN
PLACERVILLE
WOODLAND
STOCKTON
MODESTO
MERCED
MADERA
FRESNO
HANFORD
OAKLAND
SAN PABLO BAY
SAN FRANCISCO BAY
MT. DIABLO BASE LINE
MT. DIABLO MERIDIAN
GLENN
BUTTE
YUBA
PLACER
AMADOR
CALAVERAS
TUOLUMNE
MARIPOSA
FRESNO
KINGS
SAN JOAQUIN
SACRAMENTO
SUTTER
YOLO
LAKE
NAPA
SONOMA
SOLANO
ALAMEDA
SANTA CLARA
STANISLAUS
MERCED
SAN BENITO
MONTEREY
SAN LUIS OBISPO
SANTA BARBARA
VENTURA


HANFORD
19
20
22

CROSS SECTION OF THE SACRAMENTO VALLEY (near Colusa)

Annual rainfall at Biggs 22.10"
" " " Colusa 15.12"

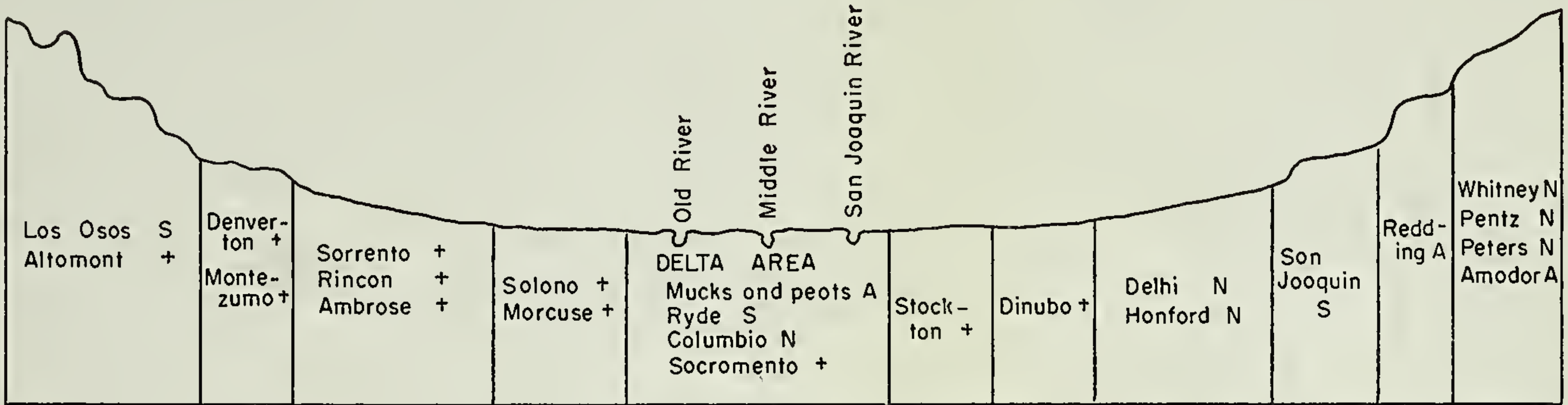


Soils	PARENT MATERIAL	DRAINAGE CONDITIONS	ALKALI
Hugo A, Maymen S, Henneke N	Sedim'ntary-Serpentine	Good	Free
Venado +	Serpentine	High water table	
Contra Costa N, Ayar ++	Sedimentary	Good	
Corning S	Mixed		
Yolo N, Zamora N	Sedimentary		
Genevra +, Willows +		High water table	Mod. to strong white alkali
Sacramento +, Sycamore +, Columbia N, Marvin +	Mixed	Subject to overflow	Spotted alkali conditions, mostly white alkali
Stockton +, Gridley N	Mostly basic igneous		
Columbia N	Mixed		
Honcut N, Wyman N	Mostly basic igneous	Good	Free
San Joaquin S	Mixed	Perched water table during wet season	
Redding A			
Aiken S, Mariposa A	Basic igneous slates	Good	

N = Neutral
\+ = Calcareous subsoil
++ = Calcareous throughout
S = Slightly acid
A = Moderately to strongly acid

CROSS SECTION OF THE SAN JOAQUIN VALLEY (near Stockton)

Annual rainfall at Stockton 14.11"
" " " Antioch 12.25"



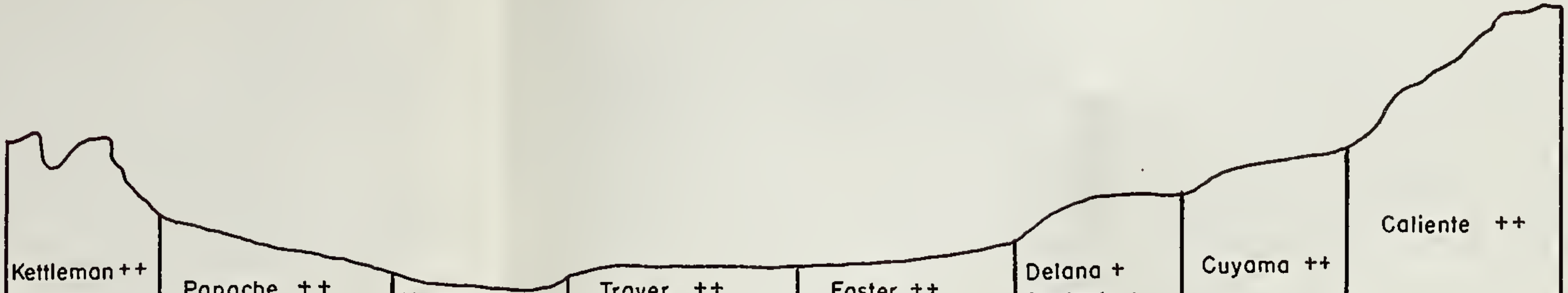
PARENT MATERIAL	Sedimentory				Orgonic moteriols ond Mixed moteriols	Mostly bosic	Gronitic		Mixed		Sedimentory
DRAINAGE CONDITIONS	Good			High woter toble	Subject to overflow		High woter toble	Good	Perched woter toble during roiny seoson		Good
ALKALI	Free		Usuolly free	Strong white olkoli	Some spots of olkoli, mostly white olkoli		Spotted white & block olkoli	Usuolly free	Free		

N = Neutrol
\+ = Colcoreous subsoil
++ = Colcoreous throughout
S = Slightly ocid
A = Moderotely to strongly ocid

LOCATION OF AREAS
MERCED
FRESNO
KINGS
KERN
SAN BENITO
HOLLISTER
MONTEREY
SAN LUIS OBISPO
SAN LUIS OBISPO
SANTA BARBARA
LOMPOC
SANTA BARBARA
VENTURA
VENTURA
LOS ANGELES
LOS ANGELES
SANTA ANA
ORANGE
SAN BERNARDINO
SAN BERNARDINO
RIVERSIDE
RIVERSIDE
SAN BERNARDINO BASE LINE
SAN BERNARDINO MERIDIAN
SAN DIEGO
SAN DIEGO
PACIFIC OCEAN
OCEAN

CROSS SECTION OF THE SAN JOAQUIN VALLEY (near Bakersfield)

Annual rainfall at Bakersfield 6.12"
" " " Maricopa 5.69"

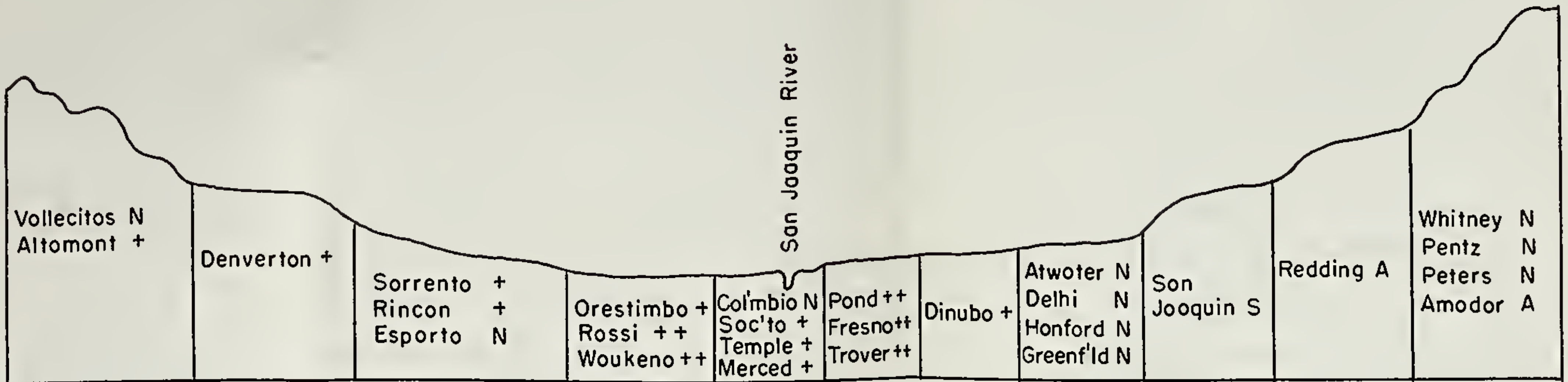


	Kettleman ++	Panache ++ Last Hills ++	Merced + Temple + Sacramento + Tulare ++	Traver ++ Pond ++ China + Fresno ++	Foster ++ Cajon ++ Hesperia + Exeter +	Delano + Adelanto + Madera +	Cuyama ++	Caliente ++
PARENT MATERIAL	Sedimentary		Mixed	Granitic			Mixed	Sedimentary
DRAINAGE CONDITIONS	Good	Good	High water table Subject to overflow	High water table	Foster soils have flucuating water table Others good	Good		
ALKALI	Occasionally some white alkali	Panache - Occasionally some white alkali Lost Hills - Usually some white alkali	Spotted alkali, both white and black	Pond - Strong, white and black alkali China - Spotted alkali - white and black	Foster and Cajon - Spotted alkali - white and black Others usually free	Free	Occasionally some white and black alkali	Free

++ = Calcareous throughout
\+ = Calcareous subsoil

CROSS SECTION OF THE SAN JOAQUIN VALLEY (near Merced)

Annual rainfall at Merced 11.81"
" " " Newman 10.06"

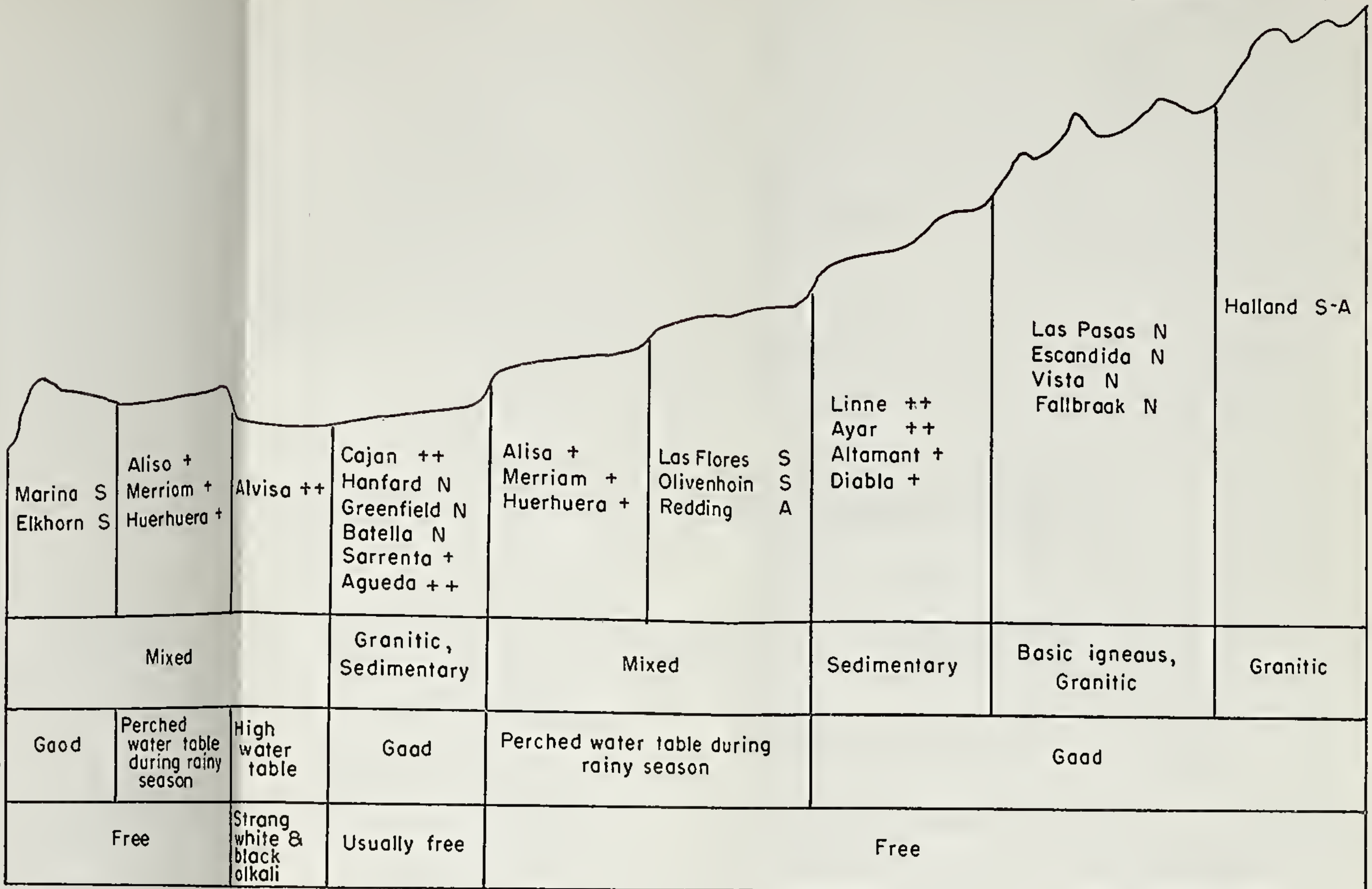


	Vollecitos N Altomont +	Denverton +	Sorrento + Rincon + Esporto N	Orestimbo + Rossi ++ Waukeno ++	Colmbio N Soc'to + Temple + Merced +	Pond ++ Fresno ++ Trover ++	Dinubo +	Atwoter N Delhi N Honford N Greenf'ld N	Son Jooquin S	Redding A	Whitney N Pentz N Peters N Amodor A
PARENT MATERIAL	Sedimentory			Sedimentory & Gronitic	Mixed	Granitic			Mixed		Sedimentory
DRAINAGE CONDITIONS	Good			High woter toble	High woter toble Subject to overflow	High woter toble	Fluctuoting woter toble	Good	Perched woter toble during roiny seoson		Good
ALKALI	Free	Usuolly free	Usuolly free	Orestimbo, some white olkoli Rossi-Wouk., strong, white & block olkoli	Spotted olkoli, white & block	Strong olkoli, white & block	Spotted olkoli, white & block	Free			

++ = Colcoreous throughout
+ = Colcoreous subsoils
N = Neutrol
S = Slightly ocid
A = Moderotely to strongly ocid

CROSS SECTION OF COASTAL AREA (near San Diego)

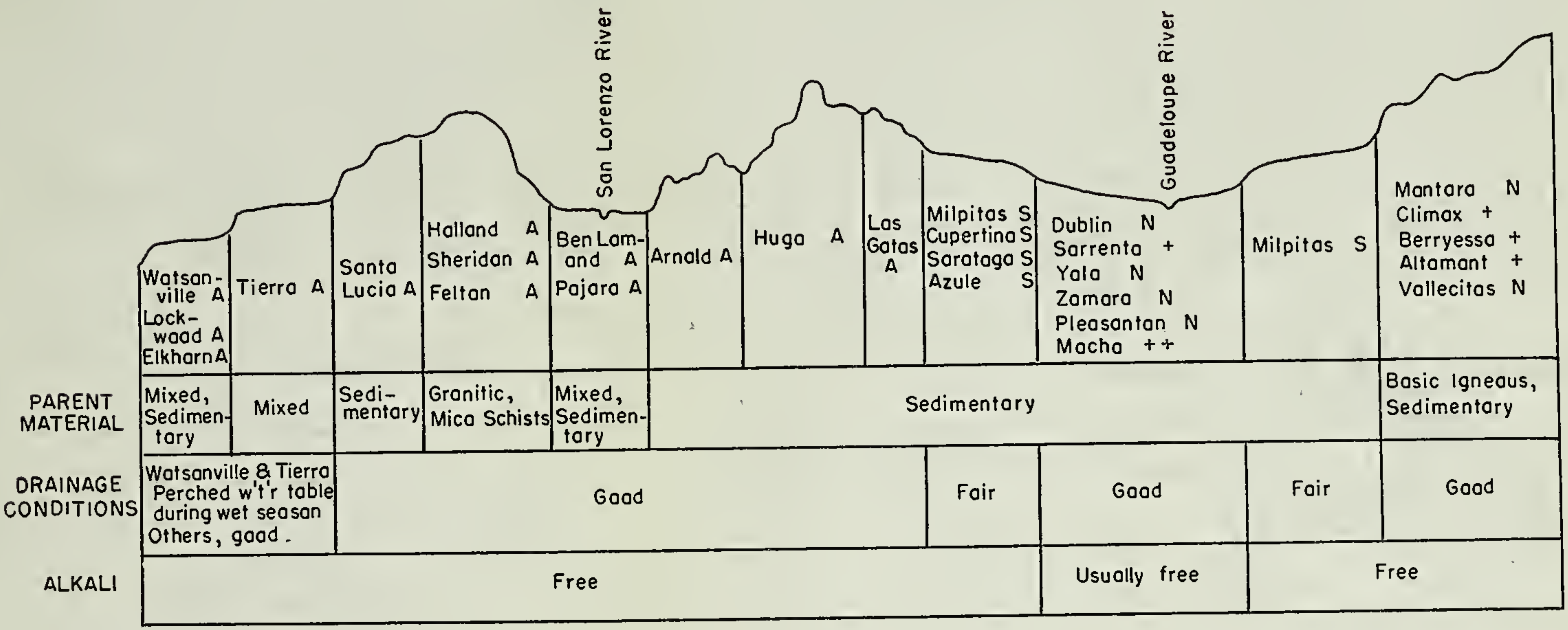
Annual rainfall at San Diego 10.30"
" " " El Cajon 13.92"
" " " Cuyamaca 39.87"



N = Neutrol
\+ = Calcoreaus subsoil
++ = Calcareous throughout
S = Slightly acid
A = Moderotely to strongly acid

CROSS SECTION OF COASTAL AREA (near Davenport and San Jose)

Annual rainfall at	*Santa Cruz*	*26.13"*
" " "	*Ben Lomond*	*55.91"*
" " "	*Los Gatos*	*29.62"*
" " "	*San Jose*	*13.93"*
" " "	*Lick Observ.*	*27.47"*



N = Neutral
\+ = Calcareaus subsails
++ = Calcareaus thraughaut
S = Slightly acid
A = Maderately ta strangly acid

CROSS SECTION OF COASTAL AREA (near Santa Barbara)

Annual rainfall at	*Santa Barbara*	*18.90"*
"	*San Marcus Pass*	*30.66"*
"	*Los Alamas*	*15.84"*

									Santa Ynez River			
	Marina A Milpitas S Mantezuma +	Alvisa ++ Clear Lake +	Agueda ++ Sarrenta + Yola N Mocha ++	Milpitas S Mante-zuma + Alisa +	Olivenhain S	Nacimienta ++ Sespe + Gaviata N Santa Lucia S-A Maymen S	Raugh mtn. land	Santa Ynez N Bal-lard S	Metz ++	Santa Ynez N Ballard S Cach-uma S	Chamise A	Raugh braken land
PARENT MATERIAL	Mixed (mastly sedimentary)	Sedimentary		Mixed (mastly sedimentary)		Sedimentary		Mixed (mastly sedimentary)				
DRAINAGE CONDITIONS	Perched water table during wet season	High water table	Gaod	Perched water table during wet seasan		Gaad		Fair	Gaod	Fair	Perched water tble during wet seasan	
ALKALI	Free	High Variable white alkali	Usually free	Free					Usually free	Free		

N = Neutral
\+ = Calcareous subsoils
++ = Calcareous throughout
S = Slightly acid
A = Moderately to strongly acid